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for project
'DEPLOYMENT OF A REGIONAL ARRAY IN NORWAY'

by
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1. SUMMARY

This report gives an account of the progress of all work associated with the deployment of a new regional array in Norway.

The purpose of the development of an experimental regional array in Norway is to take advantage of the extremely good propagation of high-frequency energy for regional seismic phases in Eurasia. Since Norway is located within the same geologic plate boundary as the Soviet Union, the deployment of such an array in Norway will provide important new insight with respect to the projected performance of possible future in-country stations in the U.S.S.R.

The array is currently being implemented as a joint undertaking between NORSAR and the Sandia National Laboratories, Albuquerque, NM, USA. According to present plans and progress, the new array will be operational on September, 1, this year.

In the reporting period, agreements with landowners on use of their land has been reached. An engineering consultancy company has been hired to do planning of all construction work for the new array. The same company also assisted in the selection of contractors for the field work and is also doing the regular inspection of performance and progress of all contractors.

The actual field work started in March with the deployment of the seismic vaults and drilling of two boreholes for seismometers. A central terminal building was completed in June. Trenching and cable-lying started in June and will be completed in August. It is anticipated that all field work by contractors will be finalized on August 15, allowing Sandia represesntatives to start implementing the system on August 1, and continuing their work unimpeded until completion of system deployment.

The administrative work related to transmission of data from the new array, both to various locations in the U.S. via satellite and to the NORSAR Data Processing Center at Kjeller, via a new digital land line, has progressed satisfactorily.

An IBM 4341 Model K10 processor has been purchased during the reporting period. This processor will be used for on-line processing of the data from the new array received at Kjeller.

II. GENERAL BACKGROUND

The purpose of the development of a experimental regional array in Norway is to take advantage of the extremely good propagation of high-frequency energy for regional seismic phases in Eurasia. Since Norway is located within the same geologic plate boundary as the Soviet Union, the deployment of such an array in Norway will provide important new insight with respect to the projected performance of possible future in-country stations in the U.S.S.R.

The array is currently under construction in Norway as a joint enterprise between Sandia National Laboratories, Albuquerque, U.S., and NORSAR. According to present plans and progress, initial data from the array will be available from September 1, 1984. Seismic data will be transmitted via satellite to several recipients in the U.S., and via a 64 Kbits/s digital land line to NORSAR Data Processing Center at Kjeller.

Sandia's role in the joint undertaking has been the design and engineering of the electronics of the array system. Sandia representatives will be present in Norway this summer for the field deployment and subsequent testing of seismometers, amplifiers, intra-array communication, central microprocessors etc.

Over the past four years, NORSAR has conducted extensive field experiments to assess the potential of regional arrays in detection and location of regional seismic events. Results obtained from this work has been directly utilized in the planning and design work for the new array. The current and previous NORSAR research contracts with DARPA have contained several tasks that relate directly to the processing of data from regional arrays like the new NORESS array now being implemented. In particular, a preliminary processing package (RONAPP) for on-line detection and location of regional seismic events has been developed and tested. The data from the new NORESS array will be subjected to real-time processing using the RONAPP algorithm and future modifications of it.

For the current FY, DARPA has provided funds for the initial deployment of the new array. In addition, an IBM 4341 computer which will be used for on-line analysis of data from the new array, has been purchased during the reporting period. This computer is the first item acquired for the new processing center at Kjeller. Additional items have been proposed for the FY85 budget.

NORSAR's involvement with the deployment of the new array is related to the site preparation. All construction work (trenching, acquistion and deployment of vaults, drilling of boreholes and the construction of a central terminal building in the array) is organized, supervised and administered by NORSAR, with the actual construction work being contracted to local construction companies. This report gives an account of the progress in the field work. A complete description of the array with trenches, vaults, boreholes and central terminal building will be included in the Final Report, due 30 Jan 1985.

Also included in the present report is a description of work related to the future transmission of the seismic data via satellite to the U.S. and also via digital land line to the NORSAR data processing center at Kjeller.

III. MISCELLANEOUS ACTIVITIES RELATED TO THE FIELD WORK

III.1 Land acquisition

The landowners affected by the new array were all approached during the fall of 1983. A lumbering company is the major landowner in the area. In addition to this company, three other landowners are affected, each of these having no more than one seismic vault and a trench less than a couple of hundred meters long on their land.

Contracts have been negotiated with all landowners and were signed in December 1983. The three minor landowners all accepted a nominal compensation (to be paid once) for the future inconvenience of having installations and trenched cables on their ground. With the major landowner different agreement was reached. For an amount to be paid yearly, he has accepted to make sure that the array site stays quiet in terms of local noise that could be potentially harmful to the seismic data. In addition, yearly amounts will be paid for use of roads in the area and for the inconvenience represented by the presence of the array.

III.2 Planning and inspection of construction work

Østlandskonsult A/S, an independent engineering consultancy company was hired to work out the detailed plans for all site construction activities. All plans and specific description were completed in January and tender documents were distributed to potential bidders after public announcements.

Østlandskonsult A/S assisted in the evaluation of bids and the selection of contractors for the various jobs, and by the end of March, all contracts were placed.

Østlandskonsult A/S was also contracted to do inspection and control of all field activities by the construction companies. This work has been done in close cooperation with NORSAR personnel.

III.3 Coordination meetings

During the reporting period, meetings have been held both in Norway and Albuquerque for coordination of this summer's field work.

In January, during a meeting in Albuquerque, detailed information was exchanged to a level that permitted finalizing of all plans regarding the array construction work.

In March, representatives of COMSAT, Sandia and NORSAR met in Norway to discuss matters related to the satellite transmission of data to the U.S.

Another planning meeting took place in Albuquerque in early May. Apart from deployment work this summer, future operation of the array was discussed during this meeting.

Since late May Sandia representatives have been present in Norway. They will stay in Norway until all implementation work has been completed this fall.

III.4. Transportation

The first shipment from Sandia with about 60 tons of cables, terrain vehicles and antenna equipment arrived in Oslo on a commercial vessel on May 30. NORSAR's handling agent cooperated with the U.S. Air Force Transportation Office in Oslo on customs clearance, and arranged transport to the array site.

The second shipment (about 10 tons of equipment) arrived by direct flight from Albuquerque to Oslo on July 25. Customs clearance and transport was done as before.

IV. FIELD WORK

The geometry of the new array is shown in Fig. IV.1. The elements of the array are organized in four concentric rings around the center. The central element is a 3-component instrument in a 60 m deep borehole. The remaining 24 elements are deployments in shallow vaults. (21 instruments recording vertical ground motion only, and 3 3-component systems). Data are transmitted within the array via buried cables to the central terminal building situated close to the central element in the array geometry. From this building the seismic data will be transmitted via satellite to the U.S. and also via a land line to Kjeller.

IV.1 Trenching and cable-lying

It takes about 15 km worth of trenches to connect all sites in the array with the central terminal building. Approximately 28 km of fiber optic signal cables and 44 km of power cables (all supplied by Sandia) are to be placed in the trenches, which are generally 60 cm deep. The operations started with clearing of paths for the trenches during the winter of 1984. This work was done by the major landowner in the area. The contractor chosen for the trenching and cable-lying operations started work in mid-June. The procedure chosen is to string out all cables along the trench path then run the back-hoe over the path for the trench digging, followed by placing all cables in the trench and finally backfill gently (by hand for the upper 15 cm of overburden) to avoid damage to cables. This work has proceeded generally in accordance with the planned progress with an estimated completion date of August 15.

IV.2. Boreholes

The array will have two boreholes, one at the center point of the array geometry (Fig IV.1) and the other about 5 m away from the first one. These holes are to house a 3-component short-period instrument and a 3-component broad-band instrument, respectively. Hole depths are 60 m with an inside diameter of 231.9 $\pm$ 5 mm.

The holes were drilled in the spring of 1984. Acquisition of the tube casings and their actual deployment in the holes by injection of concrete grout between the tube casings and the hole walls was completed early July.

Hole-locks provided by Sandia have been deployed in the holes. A hole-lock orientation survey has been undertaken by the Stavanger, Norway office of Sperry-Sun. This survey has also shown that the inclination of the two holes is 0.58 and 0.82 degrees, which in both cases is well within the requirement of 2.5 degrees.

IV.3. Element vaults

It was decided to use prefabricated bottomless fiber glass tanks for t 24 shallow vaults in the array. In addition to being economically favo - able (actual tank based on standard units from the manufacturer), this approach was believed to the best solution to the problem of achieving absolutely waterproof vaults. It was clear at an early time that a couple of the vaults would have to be placed in locally flat and swampy places, which could have presented severe problems to avoiding water leakages in conventionally built concrete vaults.

A sketch drawing of a fiber glass tank is shown in Fig. IV.2. 24 tanks were aquired during February and March and the deployment work started in March. After excavating the soil, a hole approximately 3 m deep was blasted and a concrete pad was prepared at the bottom. The tank was then placed on top of this pad and sealed using water proof epoxy cement. Backfilling was done carefully to prevent damage to the side walls of the tank. The work with the deployment of the shallow vaults was completed on July 1. The solution adopted for the element vaults appears to be successful, and only one minor leakage has been identified so far.

IV.4. Central terminal building

Fig. IV.3. shows the central terminal building. The building is located 10 m away from the center of the array geometry. The contractor chosen for constructing the building completed it on June 15 after a two months effort.

The larger room underground is for the central processor for acquisition, control and transmission of the data from the 36 seismometers in the array. In addition, this room provides work space for future maintenance and repair services. The smaller room underground will house batteries, which need a separate well ventilated room due to hydrogen leakage.

The 4.5 m diameter satellite antenna is placed as shown in Fig. IV.3. It faces an INTELSAT satellite in position 213.54° from true worth at an elevation of 16.8°. A hypolon cover, which is transparent to the radio signals, constitutes the wall of the antenna building which faces the satellite. The ground in front of the building has been cleared for trees to provide free sight for the antenna.

IV.5. Summary of field work

All field work has progressed according to scheduled plans or with minor delays. Some time margins were, however, built into the original progress schedule, in order to make sure that all work by the contractors would be completed by August 15, 1984. As of July 31, 1984 there is every indication that all constructing work will be completed on or before this date. This will allow the Sandia representatives to start system implementation work on August 1 and to continue their work unimpeded until completion of system deployment, and to start transmission of seismic data from the new array in September this year.

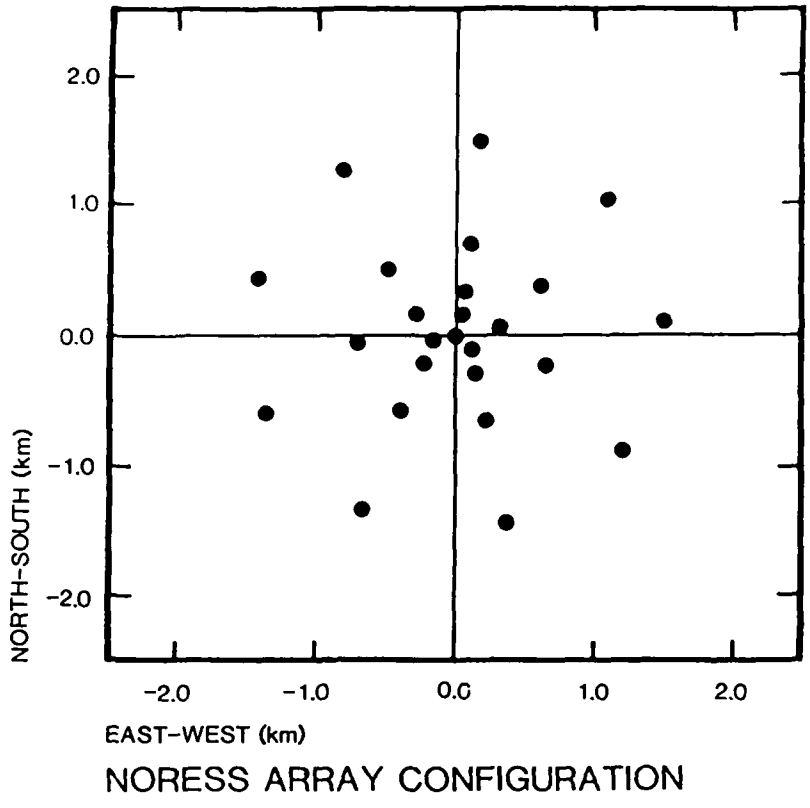

Fig. IV.1 Geometry of the new regional array in Norway.

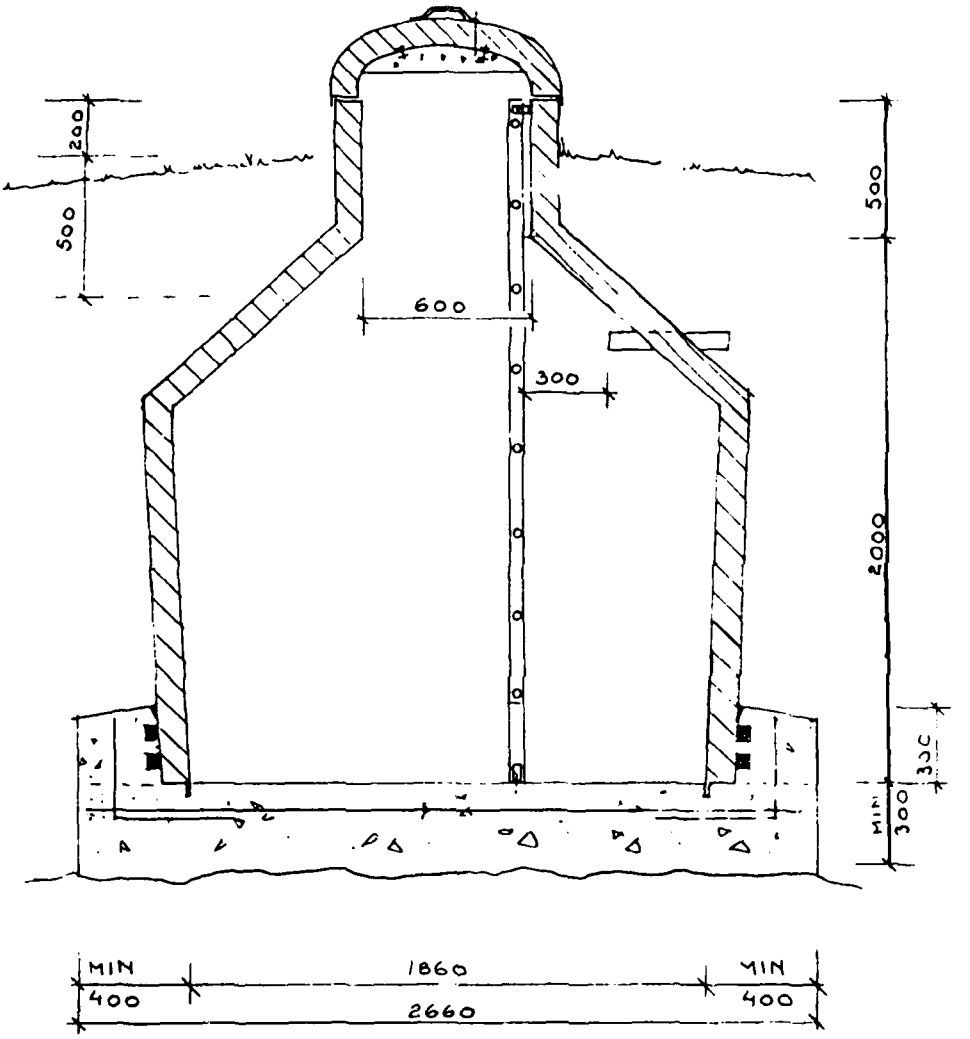

Fig. IV.2. Sketch of fiber glass tank for deployment of seismomters. All measures in mm.

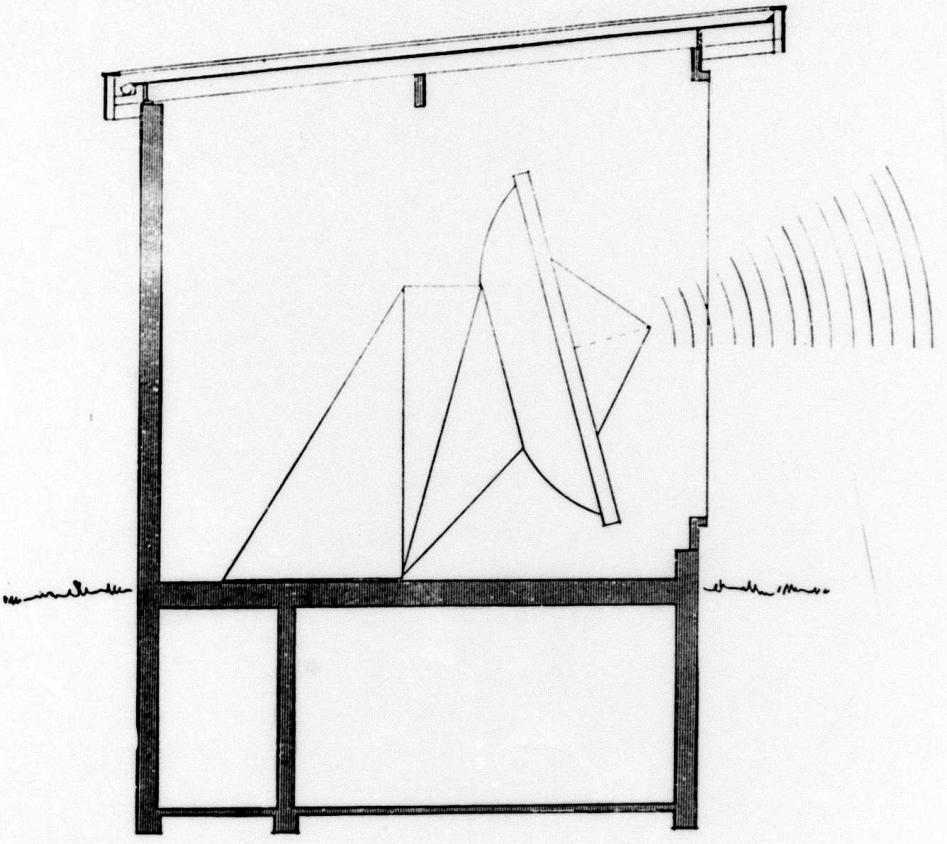

Fig. IV.3. The central terminal building with the antenna for satellite transmission of data.

V. DATA TRANSMISSION

V.1. Satellite transmission of data to the U.S

During the reporting period, several meetings have been arranged with the Norwegian Telecommunications Administrations (NTA), with discussions on data transmission via satellite to the U.S. In January, NTA applied to INTELSAT for approval of a non standard earth station for data transmission from the new array. The INTELSAT Board of Governors approved of such an earth station in March. By contract between COMSAT General and Sandia, COMSAT is to provide this satellite service from Norway to various locations in the U.S. In agreement with NTA's conditions (NTA being responsible towards INTELSAT for the operation of the earth station in Norway), the licence and provisional ownership of the antenna equipment located in Norway resides with NORSAR.

NTA has also allowed NORSAR to operate and maintain the antenna station and a contract between COMSAT and NORSAR on these matters is currently being negotiated. A dedicated telex line from NTA's control center in Oslo to the antenna site will allow NTA to control the transmitter high voltage supply.

The mechanical parts of the satellite antenna were erected inside the central terminal building in late June. Remaining installation work and testing of antenna operation will take place mid-August.

V.2. Land line to Kjeller

The seismic data from the new array will be transmitted to Kjeller via a new 64 Kbits/s digital line. NTA's work with this new line has generally progressed according to plans, and the line will be available on August 15. Preparatory work at Kjeller, associated with the reception of seismic data via the new digital line has progressed satisfactorily.

VI. EQUIPMENT PURCHASED

An IBM 4341 Model K10 processor has been purchased during the reporting period. This processor will be the central unit in the on-line processing of data from the new array. A preliminary version of a processing package for analysis of array data has been implemented and tested on data collected from a temporary array installation.